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## PREScribed BURNING INCREASED NITROGEN AVAILABILITY IN A MATURE LOBLOLLY PINE STAND

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### ABSTRACT

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Prescribed burning is a common management practice in loblolly pine (*Pinus taeda* L.) ecosystems. Several studies have examined the volatilization losses of nitrogen (N), but little information is available on subsequent availability of N. We examined the effects of a low-intensity prescribed fire in a mature stand of loblolly pine and found no significant reduction in the N content of the forest floor. However, the decomposition rate of the forest floor more than doubled for the first growing season after burning. This decomposition released 60 kg N ha<sup>-1</sup> more than measured for an unburned portion of the same stand. Increased N availability was also indicated by analysis of foliage and soil incubations. This pulse of available nitrogen may have a fertilization effect on pine growth and might substitute for late-rotation applications of N fertilizer.

### INTRODUCTION

About 1 million ha are prescribed burned annually in the Southeastern United States (Kodama and Van Lear, 1980; Richter et al., 1982), and this regional use of fire is perhaps greater than anywhere in the world (Christensen, 1981). Prescribed fires are used to prepare harvested sites for pine regeneration, control hardwood understory competition, reduce forest floor fuel loads (and risk of wildfire), control certain tree diseases, and improve wildlife forage and habitat.

Concern has been expressed since the 1930s that prescribed burning may have undesirable effects on nutrient pool sizes and fluxes (Fowells and Stephenson, 1934; Wahlenberg, 1935; Isaac and Hopkins, 1937). Particular attention has focused on nutrient loss pathways such as volatilization, ash convection, runoff, wind and soil erosion, and leaching of fire-released nutrients (for reviews see Wells et al., 1979; Woodmansee and Wallach, 1981;

again offset from previous sample points by 0.5 m. This permitted later separation of new litterfall from older forest floor materials.

Three weeks after the burn (2 May 1983), ion exchange resin bags (Binkley and Matson, 1983) were placed at the Oa/mineral soil interface and at 10 cm below the mineral soil surface every 3 m along each transect ( $n = 30$  per area, per depth). A hand trowel was inserted horizontally into the soil at the desired depth, and the resin bags were slipped in as the trowel was removed. Each bag contained 14 ml (3.7 g oven-dry weight) of mixed-bed resin (J.T. Baker No. M-614), supplying exchange capacities of 9.0 meq/bag for cations and 7.8 meq/bag for anions. Unfortunately, 9.5 cm of rain fell between the time of the burn and placement of the resin bags; any rapid flush of ammonium and nitrate (e.g. Lewis, 1974) would have been missed by the resin bags. Therefore, the resin bags should index the residual effects of the fire on N availability rather than the direct combustion effects.

Sampling of the forest floor and mineral soil was repeated six months after the burn (14 October 1983) from beneath the nylon screens. Resin bags were also collected. Foliage samples were obtained with a shotgun from the lower, west-facing crowns of 10 randomly selected pines in each plot.

On return to the laboratory, forest floor samples were air-dried and separated into coarse and fine fractions using a 4-mm mesh screen; these are roughly analogous to the Oi and Oe + Oa (or L and F + H) horizons. All weights are expressed on an oven-dry, ash free basis.

Aerobic incubations assessed nitrogen mineralization potentials (after air-drying) of the fine-fraction of the forest floor and mineral soil. Incubations used 5.0 g forest floor samples with 10 ml of deionized water in capped cups. Caps had small holes to allow for gas exchange, and water content was replenished (based on cup weight) weekly. Mineral soil incubations used 20 g samples with 7.0 ml of deionized water. After 28 days at 20°C, 100 ml of 1 N KCl were added to each cup, which were then shaken for 30 minutes and allowed to equilibrate overnight. Paired subsamples were extracted prior to incubation to provide initial concentrations. Samples were stored at 3°C for up to one week before analysis. Ammonium-N was determined by the cyanurate/salicylate reaction (Crooke and Simpson, 1971), and nitrate-N by the automated cadmium reduction method (EPA, 1974). Analyses were performed using a Technicon AutoAnalyzer II. All concentrations were calculated from regression equations based on measurements of standards; and corrections were applied for background absorbance, as indicated by blanks. Net ammonification and net nitrification were calculated as the difference between the post-incubation concentration and the initial concentration.

After collection, the ion exchange resin bags were air-dried and the resin beads were transferred to cups and extracted by shaking for 1 h with 100.0 ml 1 N KCl per cup. After settling overnight, the extracts were filtered and analyzed for ammonium and nitrate as described above. This extraction procedure does not recover all adsorbed ammonium and nitrate, but does

TABLE 2

Net ammonification and net nitrification (means of 30 and 15 samples for forest floor and mineral soil respectively; standard error in parentheses)

Plot	Date	Forest floor, <4 mm		Mineral soil, 0-10 cm	
		Net ammonification (mg N kg <sup>-1</sup> )	Net nitrification (mg N kg <sup>-1</sup> )	Net ammonification (mg N kg <sup>-1</sup> )	Net nitrification (mg N kg <sup>-1</sup> )
Control	April	100 (21)a	3.5 (1.2)a	25.4 (3.0)a	0.03 (0.01)a
	October	32 (21)b	-2.8 (0.4)b	19.1 (1.8)a	-0.13 (0.01)a
Burn	April				
	Pre-burn	93 (23)a	3.2 (0.6)a	18.2 (1.4)b	-0.10 (0.01)a
	April				
	Post-burn	181 (23)c	2.5 (0.6)c	14.2 (1.3)c	-0.11 (0.01)a
	October	70 (22)b	-5.9 (0.5)d	28.1 (2.9)d	-0.41 (0.01)b

Common letters within columns denote homogenous subsets at  $P < 0.05$ .

fraction for a total net loss of 2.3 Mg ha<sup>-1</sup> (Table 1). A similar pattern was found for total N content and distribution within the forest floor; the net loss of 12 kg ha<sup>-1</sup> was not significant. In fact, there is a 95% probability that any loss that actually occurred was less than 45 kg ha<sup>-1</sup> (based on a one-tail confidence interval of the difference between pre-burn and post-burn N contents).

For soils sampled one day after the fire, net ammonification in the fine fraction of the forest floor was double the pre-burn value (Table 2). Mineral soil incubations showed an approximate 20% reduction in net ammonification. Net nitrification remained negligible in both the forest floor and mineral soil. Rates of decomposition and N release from the forest floor after burning greatly exceeded rates in the unburned control plot. After one growing season (April-October), total forest floor weight of the burned plot decreased by an additional 7.0 Mg ha<sup>-1</sup>. The unburned plot showed significantly less reduction, averaging only 2.8 Mg ha<sup>-1</sup> (Table 1). Similarly, 63 kg N ha<sup>-1</sup> were released during this period from the forest floor on the burned plot, which was 20 times greater ( $P < 0.01$ ) than the non significant loss of 3 kg N ha<sup>-1</sup> for the control plot (Table 1).

Six months after the fire, net ammonification in the fine fraction of the forest floor was lower than in April in both the burned and control plots (Table 2). In the burned plot mineral soil, net ammonification increased to 28  $\mu\text{g NH}_4\text{-N g}^{-1}$ , twice the rate measured one day after the fire (April/post-burn). In the control plot, net ammonification was slightly reduced relative to April, and was significantly less than in the burned area. Both areas showed net immobilization of nitrate during incubation in October in contrast with slight net nitrate production in April.

The resins bags collected a sum total (ammonium-N + nitrate-N, 0 + 10 cm) of 1240  $\mu\text{g N}$  per bag in the burn versus 925  $\mu\text{g N}$  per bag in the control (Table 3). These data suggest much greater availability of nitrate (at both 0 and 10 cm depths) and ammonium (10 cm depth) in the burned plot

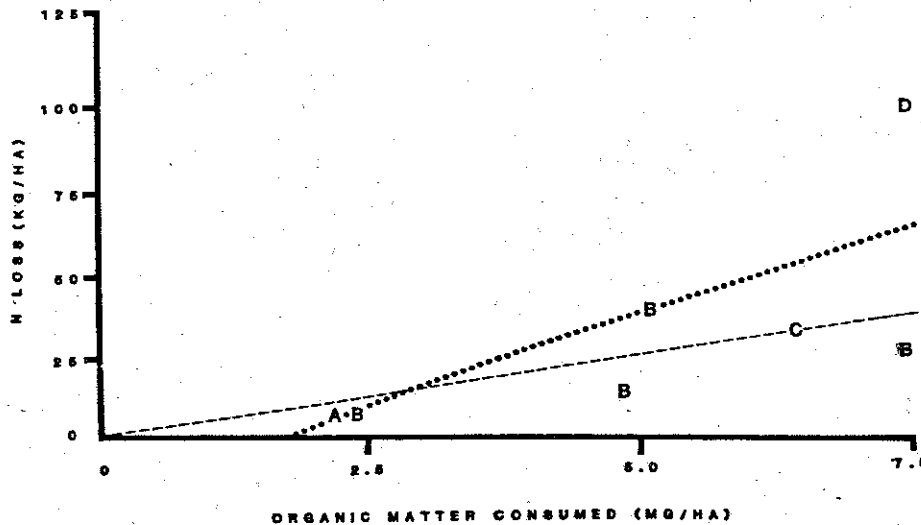


Fig. 1. Nitrogen loss as a function of organic matter combustion; A = this study,  $n = 10$ ; B = Richter et al., 1982,  $n = 55$  per point; C = Kodama and Van Lear, 1980,  $n = 12$ , D = Wells, 1971,  $n$  not given. Dotted regression line includes all points, dashed line omits D.

organic matter consumed, with N losses apparently commencing with the first organic matter losses. Additional studies are needed to verify the upper and lower ranges in Fig. 1.

Although N loss from the fire was negligible in our study, subsequent decomposition and N availability increased substantially. Part of this increase may have resulted from warmer forest floor conditions (Bissett and Parkinson, 1980; Woodmansee and Wallach, 1981). However, Grigal and McColl (1977) found no difference in rates of weight loss from litter bags placed in control and previously burned stands. For our study, we suspect that differences in substrate quality and structure probably accounted for the increased decomposition. Note that Grigal and McColl (1977) used freshly collected aspen and aster leaves rather than residual materials from the different areas. Their experiment tested only for differences in environmental factors and apparently none existed.

Our results are strikingly similar to the pattern reported by Covington and Sackett (1984) for a prescribed fire in a ponderosa pine stand. Their autumn fire appeared to reduce the N content of the forest floor by about 10% ( $44 \text{ kg ha}^{-1}$ ), but the difference was not significant. Decomposition over winter and spring (8 months) significantly reduced the forest floor N content by an additional 23% ( $108 \text{ kg ha}^{-1}$ ). We are unaware of any other studies of post-fire decomposition and nutrient release, but similar results from prescribed fires in loblolly pine and ponderosa pine ecosystems may indicate a fairly general pattern.

The combination of aerobic laboratory incubations and on-site resin bags provided some interesting insights into major effects. Although the labor-

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